CHAPTER 4

ELECTRICAL DISTRIBUTION

INTRODUCTION

As a Construction Electrician second class, you may have to supervise the installation, maintenance, and repair of overhead primary and secondary power distribution systems. This chapter will provide the necessary information to enable you to calculate electrical loads and perform fundamental tasks in the selection, by size and type, of distribution equipment. When you perform the above-mentioned tasks, remember, your primary goal should be the safety of your troops.

A power distribution system includes all parts of an electrical system between the power source and the customer's service entrance. The power source may be either a local generating plant or a high-voltage transmission line feeding a substation that reduces the high voltage to a voltage suitable for local distribution. At most advance bases, the source of power will be generators connected directly to the load.

DISTRIBUTION SYSTEMS CONFIGURATION

The configurations of four distribution systems are defined in the following paragraphs. These four distribution systems — radial, loop (ring), network, and primary selective — are briefly described. For additional information, review the *Electric Power Distribution Systems Operations*, NAVFAC MO-201.

RADIAL DISTRIBUTION SYSTEM

A representative schematic of a radial distribution system is shown in figure 4-1. You should note that the independent feeders branch out to several distribution centers without intermediate connections between feeders.

The most frequently used system is the radial distribution system because it is the simplest and least expensive system to build. Operation and expansion are simple. It is not as reliable as most systems unless quality components are used. The fault or loss of a cable, primary supply, or transformer will result in an outage on all loads served by the feeder. Furthermore, electrical service is interrupted when any piece of

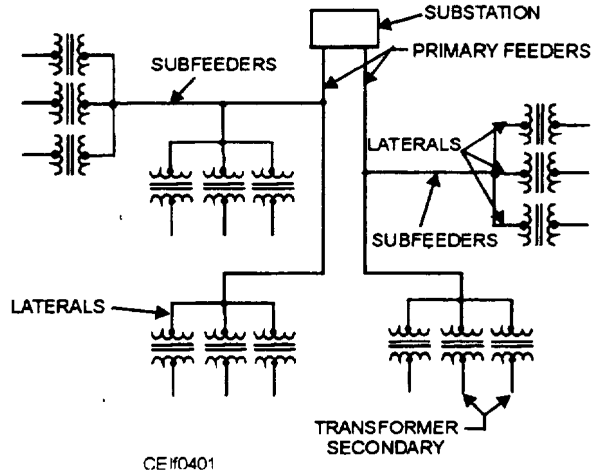

Figure 4-1.—Radial distribution system.

service equipment must be de-energized to perform routine maintenance and service.

Service on this type of feeder can be improved by installing automatic circuit breakers that will reclose the service at predetermined intervals. If the fault continues after a predetermined number of closures, the breaker will lock out until the fault is cleared and service is restored by hand reset.

LOOP/RING DISTRIBUTION SYSTEM

The loop, or ring, system of distribution starts at the substation and is connected to or encircles an area serving one or more distribution transformers or load centers. The conductor of the system returns to the same substation.

The loop system (fig. 4-2) is more expensive to build than the radial type, but it is more reliable. It may be justified in an area where continuity of service is of considerable importance, for example, a medical center.

In the loop system, circuit breakers sectionalize the loop on both sides of each distribution transformer connected to the loop. The two primary feeder breakers and the sectionalizing breakers associated with the loop feeder are ordinarily controlled by pilot wire relaying or directional overcurrent relays. Pilot wire relaying is used when there are too many secondary substations to obtain selective timing with directional overcurrent relays.

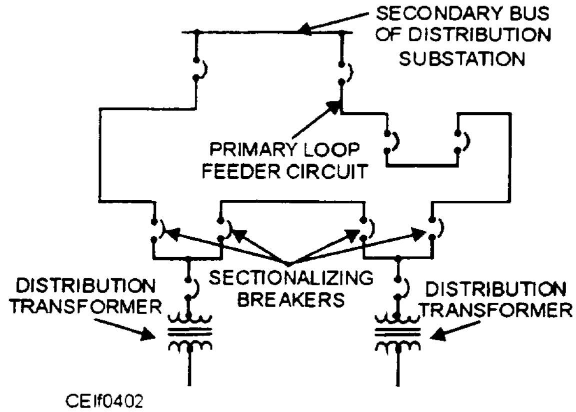

Figure 4-2.—Loop, or ring, distribution system.

A fault in the primary loop is cleared by the breakers in the loop nearest the fault, and power is supplied the other way around the loop without interruption to most of the connected loads. Because the load points can be supplied from two or more directions, it is possible to remove any section of the loop from service for maintenance without causing an outage at other load points. If a fault occurs in a section adjacent to the distribution substation, the entire load may have to be fed from one side of the loop until repairs are made. Sufficient conductor capacity must be provided in the loop to permit operation without excessive voltage drop or overheating of the feeder when either side of the loop is out of service. If a fault occurs in the distribution transformer, it is cleared by the breaker in the primary leads; and the loop remains intact.

NETWORK DISTRIBUTION SYSTEM

The network and radial systems differ with respect to the transformer secondaries. In a network system (fig. 4-3) transformer secondaries are paralleled; in a radial system, they are not.

The network is the most flexible type of primary system; it provides the best service reliability to the distribution transformers or load center, particularly when the system is supplied from two or more distribution substations. Power can flow from any substation to any distribution transformer or load center in the network system. The network system is more flexible with regard to load growth than the radial or loop system and is adaptable to any rate of load growth. Service readily can be extended to additional points of usage with relatively small amounts of new construction. The network system, however, requires large quantities of equipment and extensive relaying; therefore, it is more expensive than the radial system. From the standpoint of economy, the network system is suitable only in heavy-load-density areas where the load center units range from 1,000 to 4,000 kilovoltamperes (kVA).

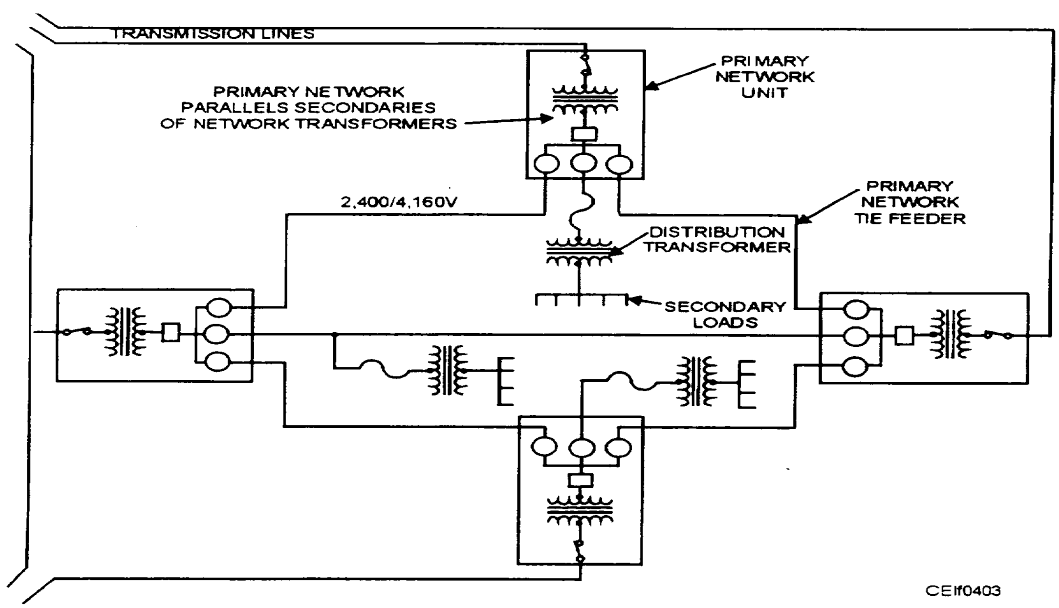

Figure 4-3.—Network distribution system.

The transformers of a secondary network distribution system are connected in parallel through a special type of circuit breaker, called a network protector, to a secondary bus. Radial secondary feeders are tapped from the secondary bus to supply loads. A more complex network is a system in which the low-voltage circuits are interconnected in the form of a grid or mesh.

If a primary feeder fails or a fault occurs on a primary feeder or distribution transformer, the other transformers start to feed back through the network protector on the faulted circuit. This reverse power causes the network protector to open and disconnect the faulty supply circuit from the secondary bus. The network protector operates so fast that there is minimal exposure of secondary equipment to the associated voltage drop.

PRIMARY SELECTIVE SYSTEM

In some instances, a higher degree of reliability can be attained with a primary selective system. Protection against loss of a primary supply can be gained through the use of a primary selective system (fig. 4-4). Each unit substation is connected to two separate primary feeders through switching equipment to provide a normal and an alternate source. When the normal source feeder is out of service for maintenance or a fault, the distribution transformer is switched, either manually or automatically, to the alternate source. An interruption will occur until the load is transferred to the alternate source. Cost is somewhat higher than the radial system because primary cable and switchgear are duplicated.

In laying out a distribution system for a base, you should divide the base into a number of sections. These sections should be chosen so that the load in each section is close to one of the distribution centers. You take this action to keep the length of the mains as short as possible and to keep the voltage drop low between the distribution and the loads. The distribution or load centers should be located as near as possible to the electrical load center.

OVERHEAD CONSIDERATIONS

In the construction and maintenance of Navy power distributions systems, you should be aware of the overhead distribution pole locations and the types of overhead distribution equipment used. An excellent source of information on distribution systems is *The Lineman's and Cableman's Handbook.*

POLE LOCATIONS

Your decision on the location of poles is limited because either you will be replacing existing poles or installing additional poles according to NAVFAC

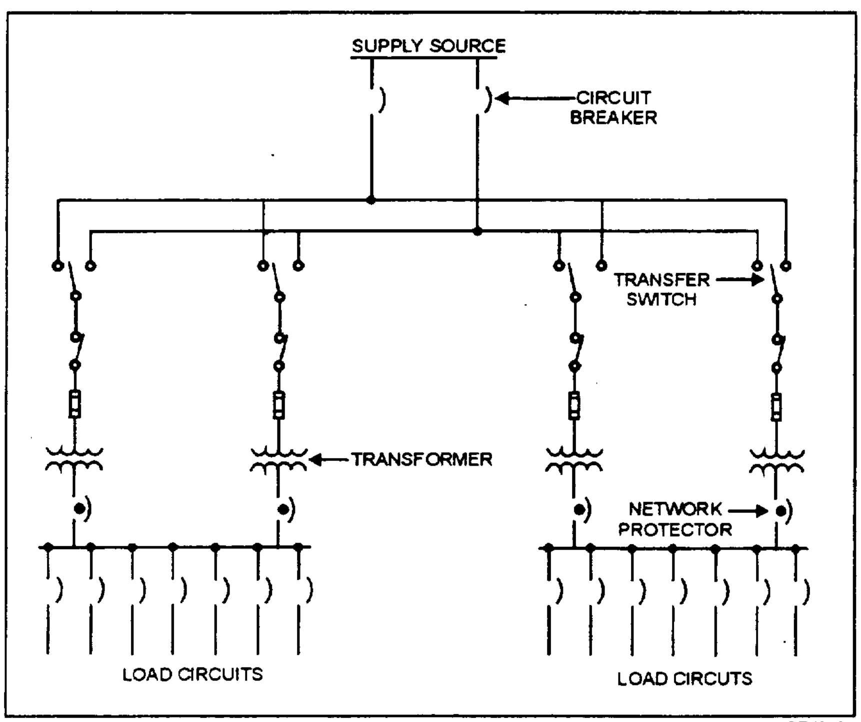

Figure 4-4.—Primary selective distribution system.

drawings and specifications. You may be asked to submit information (fact-gathering package) on a new power distribution addition to the base. If so, the following recommended actions need to be considered:

- Install utility poles in the same location, especially on upgrade projects.
- Install power distribution systems underground whenever possible.
- Conduct a survey using a map to chart the territory where the distribution lines are to be routed (for large areas, aerial photography is faster and more accurate).
- Ensure that the survey map is large enough to clearly show all buildings. roads. streams, hills, ridges. railroads. bridges. and any existing power and communications lines.
- Select the straightest and shortest route whenever possible.
- Route the new distribution system near or in the general direction of future load demands.
- Make the distribution system readily accessible for construction. inspection, and maintenance by paralleling them to existing streets and highways.
- Avoid crossing hills. ridges, and swamp areas whenever possible to reduce the possibility of lightning and wind damage. These areas also increase costs because additional materials are needed and maintenance will be more difficult.
- Coordinate with communication companies to prevent the induction of interference with their existing lines.
- Select a route that is away from residential areas and does not damage the environment.
- Keep major traffic routes free from primary, circuits. especially in nonindustrial areas.
- Keep-distribution lines on the same side of the road whenever possible.
- Avoid blocking driveways, entrances. exits. and fire escapes when installing branch lines or guys.
- Locate poles 2 feet from the curb.
- Finally. plan for future street-lighting circuits.

EQUIPMENT

Many different types and makes of overhead distribution equipment are in use today. This chapter will cover some of the standard equipment you will install and maintain, such as poles, transformers, capacitors, interrupting and protective devices.

Poles

Utility poles that support electrical lines must be designed to support the conductors, insulators, and shield conductors in a manner that provides adequate electrical clearances. A safe clearance must be maintained when the conductor temperature is elevated as a result of a large amount of current flowing in a circuit and also when the conductors are ice coated or strong winds are blowing.

The three most common types of poles that you will be working with are wood, reinforced concrete, and steel. Other types of poles in use are as follows: aluminum, fiber glass, and polysil. As a Seabee assigned to either a PWC or a battalion, you will be responsible for ordering, installing, and maintainingthe utility poles.

Power lines supported by wood-pole structures are generally considered to be the most economical. In the United States, the southern yellow pine, western red cedar, and the Douglas fir are the most commonly used species of tree. All wooden poles are given a preservative treatment (normally pressure treated) to prevent deterioration. The service life of the utility pole can be doubled by preservative treatment. Many of the older poles now in use were treated with creosote.

CAUTION

Creosote is a toxic compound that irritates the skin and sometimes causes blistering. It is also carcinogenic and is being phased out because of groundwater contamination problems. Used creosote contaminated poles may not be burned and must be disposed of in EPA approved landfills. You should use extra care when working around poles treated with creosote, avoid prolonged skin contact, and wash thoroughly after handling. Clothing contaminated with creosote should be laundered separately from family clothing.

Creosote oil, pentachlorophenol, and chromated copper arsenates have been used to provide a preservation treatment of wood poles. Newer poles are now treated with less toxic chemicals and, therefore, are safer to work with and also easier to climb (because the treatment softens the wood). They are environmentally acceptable because they do not contain materials that are toxic to mammals.

Wooden utility poles are classified by the length, circumference at the top of the pole, and the circumference measured 6 feet from the bottom of the pole. Pole sizes begin at 25 feet and are increased in 5-foot increments up to 90 feet in length. The pole top circumference increases 2 inches for every class of pole. There are 10 classes of wooden poles numbered from 1 to 10. Class 1 is the smallest and class 10 is the biggest. The American National Standards Institute's publication entitled *Specifications and Dimensions for Wood Poles* (ANSI 05.1) provides technical data for wood utility poles.

Distribution Transformers

For long-distance transmission, a voltage higher than normally generated is required. A step-up transformer is used to produce the high voltage. Most electrical equipment in the Navy uses 120/208 volts. The primary voltage distributed on Navy shore installations, however, is usually 2,400/4,160 and 13,800 volts. A distribution transformer (step-down) is required to reduce the high-primary voltage to the utilization voltage of 120/208 volts. The various types of transformer installations are discussed later in this chapter. Regardless of the type of installation or arrangement, transformers must be protected by fused cutouts or circuit breakers; and lightning arresters should be installed between the high-voltage line and the fused cutouts.

Three general types of single-phase distribution transformers are in use today. The conventional type requires a lightning arrester and fuse cutout on the primary-phase conductor feeding the transformer. The self-protected (SP) type has a built-in lightning protector; the completely self-protected (CSP) type has the lightning arrester and current-overload devices connected to the transformer and requires no separate protective devices. You should review Module 2, Navy Electricity and Electronics Training Series (NAVEDTRA 172-02-00-91) for more information on transformer theory.

In primary and secondary windings construction, the change in voltage in a transformer depends on the number of turns of wire in the coils. The high-voltage winding is composed of many turns of relatively small wire, insulated to withstand the voltage applied to the winding. The secondary winding is composed of a few turns of heavy copper wire, large enough to carry high current at a low voltage. Figure 4-5 shows a single-phase transformer with secondary windings connected in series and parallel.

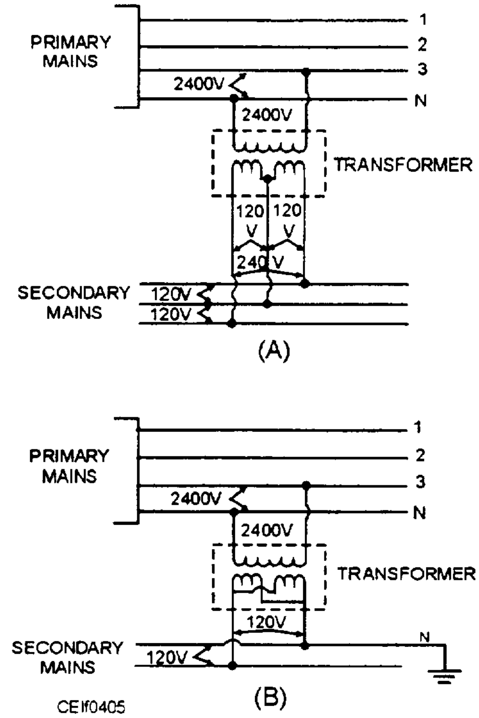

Figure 4-5.—Single-phase transformer with secondary windings connected in series and parallel.

In a distribution transformer, a secondary coil is wound on each leg of the laminated iron core, and the primary coil is wound over the secondary coils. The primary leads pass through a steel tank and are insulated from the tank by porcelain bushings. The secondary leads are connected to studs on a terminal block. Copper straps on the secondary terminal block permit connecting the two secondary coils in series or in parallel. From the terminal block, three secondary leads pass through porcelain bushings to the outside of the tank. An oil-level line inside the tank marks the level to which the tank is filled with transformer oil.

Several methods of cooling transformers are in use today, such as self-air cooling, air-blast cooling, liquid-immersed self cooling, and liquid-immersed water cooling. Self-air cooling types of transformers are simply cooled by surrounding air at atmospheric pressure; the heat is removed by natural convection (normal dissipation of heat by cooling). The self-air cooling transformer is called the dry type of transformer.

The air-blast cooling transformer has the core and windings encased in a metal enclosure through which air is circulated by a blower. This type is used for large power transformers with ratings from 12,000 to 15,000 kVA.

The liquid-immersed self-cooling transformer has its coils and core completely immersed in transformer oil. In large transformers. the tanks have external tubes or external radiators through which the oil circulates by natural convection caused by the differences in oil temperature.

The liquid-immersed water-cooling transformer is sometimes used where a plentiful supply of cool water is available. In this type, a coil of copper or brass pipe is installed near the top of the tank in the cooling oil. Water is circulated through this coil and carries away the heat from the oil as it rises in the tank.

Insulating liquids have high-insulating qualities and serve two purposes: first. they insulate the coil, and second. they help dissipate the heat generated by the resistance of the windings and eddy currents in the iron core. If this heat were not removed. the transformer would operate at excessively high temperatures, which. in turn, would damage or destroy the insulation on the coils.

Two common types of insulating liquids are mineral oil and Askarel®. Mineral oil is a nontoxic insulating liquid. It is used in different types of high-voltage electrical equipment, such as circuit breakers, switches. and transformers. Mineral oil must be kept in an airtight container, or else sludge will form. This sludge will settle in the bottom of the tank and slow the natural transfer of heat. Also the longer mineral oil is left exposed to air, the greater the loss of insulation properties.

Askarel® is a synthetic, nonflammable insulating liquid. It has other trade names, such as Pyranol®, Inerteen®, Chlorexirol®, and Asbestol®. This liquid must be handled with care because of its toxic chemical properties. Askarel® is used in special transformers for applications where flammable liquids must be avoided.

Askarel® may have an irritating effect upon the skin. eyes, nose, and lips. It also may irritate skin abrasions or tender areas between the fingers. Askarel® may contain polychlorinated biphenyls (PCBs): a toxic, carcinogenic oily liquid. Transformers tested and found to be contaminated with PCBs should have labels on the outside of the transformer warning of this hazard.

WARNING

- If assigned to work on a transformer known to be contaminated with PCBs, see your supervisor for a Material Safety Data Sheet (MSDS) for hazards and precautions. Personal protective equipment, such as impermeable gloves and chemical splash goggles, are mandatory.
- Avoid prolonged skin contact and wash thoroughly after use.
- Avoid breathing vapors.
- When removing transformer oil, wear respiratory protection. If you discover PCB transformer oil spilled on soil, immediately notify your supervisor who must notify environmental authorities and summons a trained hazardous material spill clean-up team.

To protect yourself when handing Askarel®, wear impermeable gloves. Also wear splashproof goggles. Whenever liquid comes in contact with the skin, wash it thoroughly with warm water and soap.

Ensure that the work space is properly ventilated before working on transformers containing Askarel®.

Avoid breathing Askarel® vapors. Wear an approved organic vapor cartridge respirator when vapors are present. When removing Askarel® oil which is contaminated with PCBs, air respirators may be necessary.

If a blueprint of a particular transformer installation is available to you, your job will be comparatively easy. All construction and electrical specifications will be worked out for you beforehand, and all you have to do is convert this information into a finished product. However, in some instances, a blueprint will not be available. Then it will be up to you to determine the location and size of the transformer and install it according to the latest specifications. You should be familiar with the rules and requirements of the most current electrical codes. Be sure to carefully study any applicable code requirements before installing a transformer.

Transformers are mounted on poles in various ways, such as suspended on a bracket bolted to the pole, suspended from a crossarm with brackets, or set on a platform mounted on an H-frame.

Single-phase transformers are usually hung with a through-bolt type of bracket or a cross-arm type of bracket. Figure 4-6 shows a single transformer hung with cross-arm brackets. Figure 4-7 shows a bank of three transformers of 25 kVA capacity hung the same way.